Tablet-Based Interaction for Immersive 3D Data Exploration

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1 Introduction

Effective visualization and interaction with 3D datasets that represent scans or simulations of the real world is at the heart of visualization research. Exploration and analysis are most strongly supported when both the best possible visual representations and the best possible interaction techniques are chosen. To present visual representations to users, the use of stereoscopy facilitates depth perception and thus ***high visual immersion***. To facilitate an interactive exploration of data, the use of touch-based input for visualization provides ***high immersion through interaction*** due to its directness—the input and the affected data are at the same visual location (i. e., sticky interaction), resulting in users feeling "in control of the data" [6].

Unfortunately, these two ways of achieving immersion are mutually exclusive. On the one hand, virtual objects in stereoscopic settings cannot be touched since they appear to float in empty space. Touch interaction, on the other hand, conflicts with stereoscopic display due to parallax issues as well as touch-through and invisible wall problems—it is far better suited for monoscopic displays.

Our overall vision is to enable researchers to explore 3D datasets with as much ***immersion*** as possible, arising both ***from visuals*** as well as ***from interaction***. We therefore explore ways to combine an immersive large view of the 3D data with means to intuitively control this view with touch input on a separate mobile monoscopic tablet. This combination has the potential to increase people's acceptance of stereoscopic environments for 3D data visualization since—through touch-based interaction—it puts them in control of their data. Moreover, the indirect manipulation of (stereoscopically displayed) 3D data on a personal touch device has been shown to have potentially more efficient and precise interaction than interaction directly on a large display [4].

2 A Second Screen for Visualization Control

Adding a second mobile display to an immersive visualization environment (Fig. 1) has the potential to provide additional visual feedback and thus facilitate flexible interactive data exploration scenarios. This setup is in contrast to an eyes-off, touch-only navigation with touch-enabled small devices, which has been explored in the past (e. g., [2, 3, 5]). The two-screen setup, however, requires us to consider a number of design goals and constraints to make both data views useful for the person exploring 3D data; in particular, the input on the mobile display needs to be as well-controlled and precise as possible. This implies that the tablet's view should be predominantly static such that small or large user movements in the environment do not result in ambiguous navigation commands. This relatively static tablet view exists in tandem with the stereoscopic view of the viewer which is updated based on 3D tracking to provide a true sense of immersion.

3 Interaction Design for 3D Navigation

Based on the static visualization displayed on the tablet (A in Fig. 3), we want to be able to initiate 3D navigation commands though touch input on the mobile device. For this pupose we are able to make use of existing touch-based 3D navigation techniques. We implemented

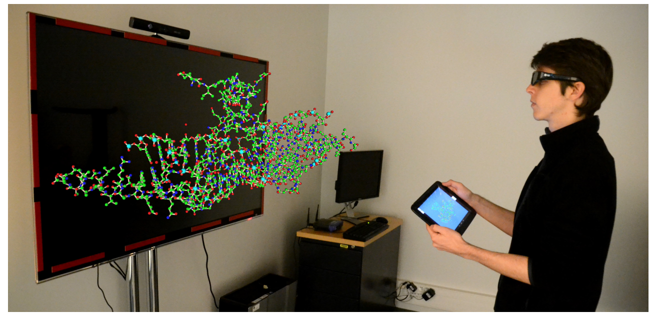

Figure 1: Tablet navigation of stereoscopically displayed 3D data.

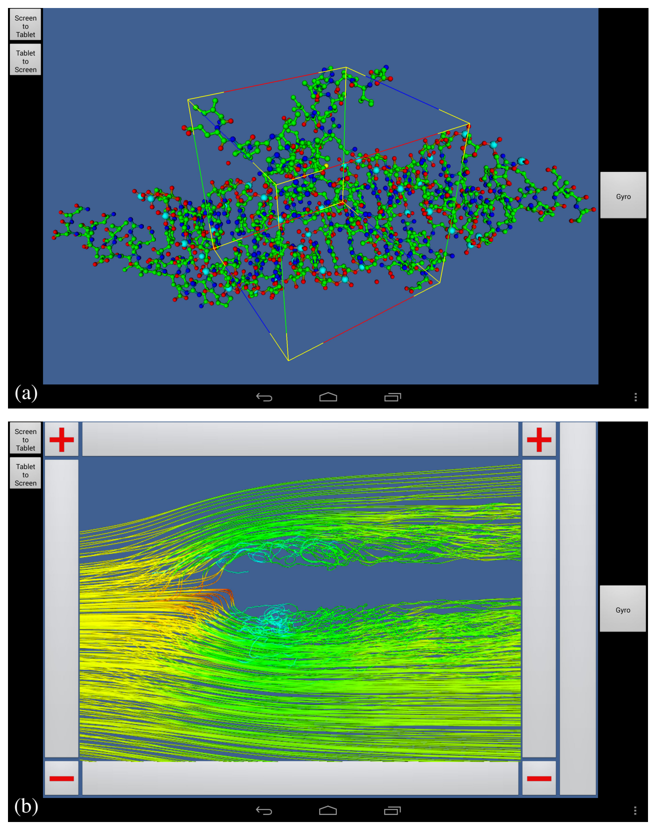

Figure 2: Tablet interface: (a) tBox and (b) FI3D.

tBox [1] and FI3D [6] (Fig. 2) because they both deliver at least 7 DOF control and can be used with finger input and without an additional stylus (B in Fig. 3). We also implemented gyroscope control (C in Fig. 3) using Android's virtual rotation sensor that is based on the tablet's gyroscope, magnetometer, and acceleration sensors. It can be activated in a spring-loaded fashion (right button in Fig. 2) to directly map changes of the tablet's orientation to rotations of the depicted 3D dataset. The resulting navigation events are sent from the tablet to the PC driving the immersive view using a client-server architecture. Also, in both interaction cases we automatically

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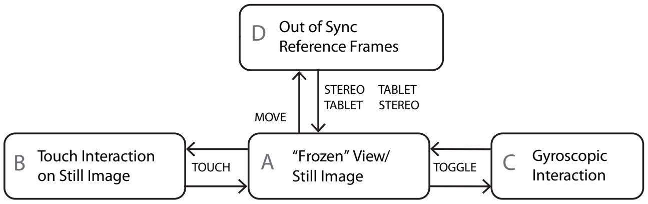

Fig. 3: Tablet-based navigation workflow for immersive visualizations.

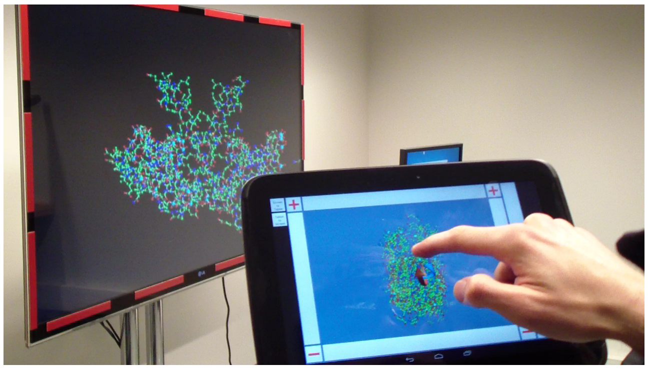

Fig. 4: Due to physically moving in the room, the immersive and tablet views can become out-of-sync. This leads to confusion for the person exploring the visualization, in particular when rotating the dataset.

and without additional return to a 'frozen' projected view of the 3D data (A in Fig. 3) after the respective manipulations—a view that matches that seen on the immersive display.

The static nature of the mobile display, however, also implies that—due to movement of the interacting user in the visualization environment—the two views (immersive and tablet) can become out-of-sync (Fig. 4; D in Fig. 3). This happens if the angle between the user's initial and current position with respect to the center location of the immersive display becomes too large—a common occurrence as the user moves around the immersive display to obtain a new view. We can thus expect a person exploring a visualization to have increasing difficulties with controlling the 3D datasets: A rotation around the x-axis, for instance, leads to a simple rolling action on the tablet's view of the dataset but is shown as rotation around a different axis in the stereoscopic view observed on the large display.

For such cases we implemented two dedicated and straightforward synchronization mechanisms: *stereo view* $\rightarrow$ *tablet* and *tablet* $\rightarrow$ *stereo view*. In the former (stereo view $\rightarrow$ tablet), the stereoscopic camera parameters from 3D tracking are used to define the tablet's virtual camera. As a result, the tablet shows the exact same view that the user sees stereoscopically at the time of the interaction. The latter (tablet $\rightarrow$ stereo view), supports the opposite effect: the stereo view is adjusted such that the interacting person sees the same VR view as was previously displayed only on the tablet. Since we cannot change the virtual camera that computes the stereoscopic view, we re-arrange the dataset such that the viewer camera shows the same view as previously shown only on the tablet.

4 Usage Scenario

We implemented an interactive visualization environment based on the described two-screen setup (Fig. 1). While the combination with large-scale (wall-sized or CAVE-like) immersive environments is certainly possible, we experimented with a smaller-scale commercial 3DTV-based hardware with time-of-flight camera 3D tracking for simplicity and ease of maintenance reasons. With this setup we specifically target the exploration of scientific 3D datasets, such as from our collaborating domain experts in fluid dynamics and structural biology (see the visualizations in Fig. 2).

In our usage scenarios, we envision that a scientist would start by loading the dataset and initialize the views such that the tablet's view is synchronized based on the person's location in the room. Then, the scientist would be able to navigate in the data using the mechanisms provided by tBox and/or FI3D, shifting his or her attention between the tablet and the immersive display as necessary. The specific widget set depends on the type of intended interactions and the type of data, and the user can toggle between both modes. By engaging the gyroscope on-demand, the scientist can access rotations otherwise difficult to achieve with the two widgets. With the help of 3D tracking, the scientist would also be able to move in the room to get alternative views of the data, benefiting from the immersion resulting from a 3D-tracked stereoscopic depiction. To avoid the confusion that results from physically moving from the initial position in the room, the scientist would make use of the described synchronization mechanisms as needed.

In particular, the tablet $\rightarrow$ stereo view synchronization would allow him or her to return to a view that was initially found useful, thereby using the tablet as a way to store a good view of the dataset. Alternatively, if the scientist finds a good view through moving in the room, he or she can continue the data exploration from that perspective by using the stereo view $\rightarrow$ tablet mechanism.

Of course, simple 3D navigation is not sufficient for effective data exploration. Therefore, we envision that the described scenario is extended with additional visual data exploration mechanisms such as selection, filtering, and parameter adjustments to support higher-level data analysis tasks. The advantage of our two-screen setup is that both displays show a representation of the data and that data exploration mechanisms can now be implemented directly on the tablet since it supports the directly-manipulative input.

5 Conclusion

We discussed our design and implementation of a system that allows people to view and explore immersive 3D data through tablet-based interactions. We demonstrated how to combine the stereoscopic view and input on the monoscopic tablet view in order to provide the user with both visual immersion and immersion through interaction. We showed that this setup can lead to situations where both views are out-of-sync, and showed that simple synchronization features can solve these problems. Our workflow can be adapted to a range of tablet interfaces—we implemented both FI3D and tBox on the monoscopic tablet interface to demonstrate a range of touch-based interfaces that could be applied to our interaction model. In the future we are interested, in particular, to examine additional data exploration techniques on the tablet.

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